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ABSTRACT

One area explored in the second (in-depth) phase of the Learning in Science Project was "children's science," defined as views of the world and the meanings for words that children have and bring with them to science lessons. The investigation reported focuses on the concept of "energy" held by 52 Form 1 to 6 students. Data were obtained by the "interview-about-instances" procedure in which students were shown diagrams on cards which represented different instances (exemplars) and non-instances (non-exemplars) of the concept. Section 1 discusses methodology. Section 2 considers important aspects of scientists' views of energy, including energy conservation, heat and work, and internal energy. Section 3 details various aspects of students' views about energy, while section 4 examines other aspects of students' answers to interview questions and their implications for teaching. Section 5 considers scientific perspectives that some students do have. Section 6 offers several suggestions, based on the finding that children have and tend to retain the everyday use of the word, for modifying/qualifying children's views to make them more scientific. Included in appendices are interview cards used (with a scientific description of the energy involved in each situation) and selected answers to the question "Where does energy come from?" (JN)

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ENERGY

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WORKING PAPER No. 17

In our view successful science teaching requires an appreciation not only of the scientists' view of the world, but also an appreciation of the language, the beliefs and the expectations which children bring with them to science classes. This working paper has developed from a study carried out in the in-depth phase of the Learning in Science Project and is one of a series of papers which explores aspects of Children's Science (see Working Paper No. 14). It is our hope that these papers portray children's views of the world and meanings for words in a way which will be useful to teachers and to curriculum developers.

In the action-research phase of the project it is our intention to attempt to build practical and useful teaching strategies based on the findings of the in-depth phase of the project. For this reason we are actively seeking comments on the findings we have detailed, and seeking information on the variety of ways teachers develop ideas associated with the topic under focus in this paper.

We would be grateful if comment and/or information could be forwarded to

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ENERGY

A Working Paper of the Learning in Science Project

Beverley Stead

September 1980

1. Introduction

In our work on children's science, we have been interested in exploring children's views of the world and meanings for words, and in comparing and contrasting these views with the scientific perspective. In this paper we consider energy.

Following this introduction, which details our investigating method and the sample of children interviewed, Section 2 considers some important aspects of the scientist's view of energy. Section 3 then details various aspects of children's views about energy, while Section 4 looks at other aspects of students' answers to the interview questions and their implications for teaching. Section 5 considers the scientific perspectives that some students do have and finally in Section 6 we consider where we go from here.

Pupils' meanings of the word "energy" were investigated using the interview-about-instances method (Osborne and Gilbert, 1979) using the instances detailed in Appendix A.

In an interview situation the pupils[1] were asked "Can you tell me about energy here?" followed by a brief description of the situation portrayed on the card. More specific questions were asked later if need be:

"Does the ..... use energy?"
"Where does the energy come from?"
"What happens to that energy?"

These questions were aimed at probing the pupil's understanding of energy changes or conversions, a basic concept of energy.

Each quotation is referenced with a number corresponding to the student who gave that response, or one like it. Form 1 students are identified with a number beginning with 1, eg 103; Form 2 with a 2, eg 208; Form 3 with a 3, and so on.

2. Aspects of the Scientists' View of energy.

Energy, and the associated words heat and work, have meanings in science which are subtly different from their usage in everyday language.

(i) Conservation of Energy Energy is defined in science in such a way that in any physical situation it is neither created nor destroyed; it is only changed from one form to another. For example, a ball falling down results in gravitational potential energy being transformed into kinetic energy. Scientists use the phrase "to use energy" as an abbreviation for "to use energy in one form and convert it into another form". Forms of energy include kinetic energy (associated with movement), potential energy (stored energy), internal energy (associated with the temperature of a body).

1 The pupils interviewed were nine Form 1 pupils (aged approximately 11 years); five Form 2 pupils (aged 12 years); twelve Form 3 pupils (13 years); two Form 4 pupils (14 years); eleven Form 5 School Certificate pupils (15 years); and three Form 6 U.E. physics pupils (16 years). A total of 52 students from 7 different schools.

(ii) Work and Heat Work and heat, both words used in everyday language, have very specific meanings in science. In a given situation the amount of energy converted from one form to another is called the work done or when energy is transferred because of a temperature difference it is called the heat transferred.

(iii) Internal energy Energy associated with the temperature of a body is called the internal energy of the body. The flow of energy into a body because of temperature difference, called heat transfer, results in an increase in internal energy. A hot body looses its internal energy as a flow of heat to the surroundings by convection, conduction or radiation and sometimes, by doing work, for example hot gases in an engine cylinder. The internal energy of a body can be considered as the random kinetic energy, and potential energy between, the atoms or molecules of the substance.

In Appendix A, a scientific description of the energy involved in each situation described on the interview cards is detailed.

3. Energy and Children's Science

In working Paper No. 14, "Reconsidering the Framework", the distinction between scientists' science and children's science was made. This section will consider those views of energy which might best be considered as children's science; those views of the world and meanings for words that children hold before being formally taught science. However, children's science is not a viewpoint held exclusively by children who have not been formally taught science, and examples elicited from older children are given also.

3.1 The word 'energy' was frequently used by children in the interviews in the everyday language sense of energetic, having energy. Most students could relate the word 'energy' to living things. Living things need or use energy to be active:

"Yes, (he's using energy), he's using his body and it takes energy to do that". (stairs, 203, 100, 107, 201, 302, 313, 503, 509)

"Yes, if you didn't have energy you wouldn't be able to get up there, you wouldn't be able to use your legs." (stairs, 307, 311, 401)

"Yes, (he's using energy), the bar's so heavy that he ... when he's holding it, he needs energy to keep his arms there, so he keeps holding the bar up, or else, if he wasn't using any energy the bar would just fall down."
(weightlifter, 102, 100, 104, 201, 206, 302, 303, 304, 310, 313, 314, 401, 501, 502, 504, 507)

"I think it will, when it gets a worm, usually it's off the ground, has to bend down and get it from there. And then he has to try and eat it." (bird, 402, 506)

"Yes (it does use energy) for the jaws to move, it's got to have muscles of the jaws to make it move and it's got to use its energy to make the jaws and also to swallow."
(bird, 201, 100, 101, 105, 107, 203, 205, 206, 311, 314, 315, 501, 503, 507, 509, 510, 602)

"The cow would have to have enough energy to stand up or (it will) just fall over, or down to eat the grass. (S)he has to have energy to bend down to eat it." (cow, 311, 106)

The reverse was also mentioned - that without energy, living things are listless, fatigued, and less active.

"He uses energy by lifting his legs up and if you'd walked up the stairs all day, you'd probably lose most of your energy and be quite tired and that." (person on stairs, 105, 102, 206)

"Yes, you get puffed which means you're using up energy."
(person on stairs, 303)

"Yes, because when they get to the top of the stairs, if they've run all the way, they're panting ... and might have sore legs."
(person on stairs, 314)

Fifteen students, of all ages, implied by their answers, the idea that living things use energy if they are exerting themselves, showing strength or fitness. This was expressed with:

"Yes, fitness and that." (person on stairs, 305, 309)

"Yes, because he has to use his muscles, to have strength to hold them up." (weightlifter 309, 103, 106, 107, 503, 508)

"Yes, well when he's running up the stairs, you .... just use your strength." (person on stairs, 402, 101)

"I can't really see it. Maybe as if the worm's pulling it - the bird is pulling the worm out of the ground, may cause a bit of physical strength." (bird, 312, 305, 313)

That younger students predominantly associated energy with living things, is evident in the following answers to the question asked at the end of each interview "Could you say, in a sentence or two, what the word 'energy' means to you?":

"Most people tend to think when you say 'energy' - you get energy from eating food and, you know, you have energy then." (108, 103)

"I reckon they (living things) need energy - a car, although it moves, I don't think it needs energy because if it eats, if it could eat well, it couldn't lose it, it couldn't use it up, it's just the petrol it's using up." (103, 301)

"Energy is the living things, you need energy to live, need it to move, and you need energy to keep you alive." (104, 105)

The ideas that things need to be living to have energy was also supported by views that non-living things don't need energy:

"No (table does not use energy to hold up the rock) ... it used to be a living thing but now... it was cut by machines and so it was dead. So it can hold things without having energy."
(rock on table, 101, 206, 302, 303, 304, 305, 315, 503, 509)

"I'd say no - not much used - no energy involved ... it's an inanimate object." (rock on table, 506, 602)

"The bike's got no energy at all, it's not a living thing." (bike 302, 206)

"A person who puts the jack up is using his energy, but it (the jack) is not living. It's not using any energy."
(car on jack, 302, 206)

"No, it's not living. No the toboggan isn't living .. it won't get up and walk away, so you can just leave it there."
(toboggan, 303)

From this point of view the reason why the non-living things moved had nothing to do with energy.

It was simply the slope or slippery surface:

"No, it doesn't need energy, just the slope of the hill, it just sort of goes down."
(toboggan, 203, 101, 204, 206, 302, 304, 305, 307, 309, 311, 313, 402)

"I don't think it (the water) needs energy because it's just falling down something, like it doesn't need anything to help it move." (waterfall 103, 100, 203, 205, 301, 302, 304, 307, 309, 310, 311, 401)

"No (the toboggan doesn't use energy) it's just got the icy slope..." (toboggan 100, 103, 108, 304, 307, 309, 310, 311, 401)

... or it was caused by gravity:

"Don't think so. It would just be gravitational force to bring it down. Nah, wouldn't use energy." (toboggan 502, 314, 509)

"No. The waterfall doesn't use energy to fall down because the gravity will pull it down." (waterfall 102, 303, 502, 511)

... or it simply moved itself:

"No (the toboggan does not use energy) it "comes down straight down without ... it just comes down by itself."
(toboggan 205, 310)

"No because it moves the hands itself, it doesn't need a human to move it." (clock 103)

To others, movement was a widely given reason for energy being involved with the non-living instances:

"Yes, because it (the water) is using it (energy) to move along..." (waterfall 503, 505, 507, 602)

"Yes (the car is using energy), it's going quite fast and it's moving." (car 206, 102, 107, 309, 310, 313, 401, 501, 503, 506, 507, 511, 602)

"Well the clock (hands) wouldn't be moving unless something had given it energy..."
(clock 100, 102, 303, 309, 315, 503, 507, 510, 602)

"Yes because of the movement, still moving down the hill as it slows down, until it stops." (bike, 309, 503, 504, 505, 507)

"I think the moon does need energy, because if it hasn't got energy, then how does it move around?"
(moon, 103, 107, 204, 205, 206, 301, 315, 402, 501, 503, 505, 507, 510, 602, 603)

"It has to have energy to move ...."
(hovercraft, 100, 304, 308, 312, 501, 503, 504, 505, 506)

The lack of movement was given as a reason for energy not been used or needed:

"No (the table does not use energy to hold up the rock) not moving. Just sitting still."
(rock on table, 308, 503, 506, 603)

"I can't see it would use it (energy) really it's the earth spinning around and around." (moon, 105, 309).

"I don't think it (the jack) does (use energy) because once you put the car up on the jack, it's just sitting there ..."
(car on jack, 309, 503, 603)

Whilst the scientists' view of energy is to some extent related to movement the possibility that movement is related to living, and to energy from the students' viewpoint, cannot be dismissed. Movement was widely used by students to classify instances as living. (See Working Paper No. 15).

Everyday language may help to reinforce this though, for example, the advertisements for natural gas as an energy source, use the phrase "living flame".

This association of energy with mainly living things may also reflect the sequence of topics in the Form 1 - 4 syllabus. Many Form 1

teachers teach the unit "Community Organisation", involving food chains, at the beginning of the year as the weather is suitable then for field work. Energy in the biological work is often taught before and out of context with other types of energy.

3.2 Twelve students, at least in one instance, related energy to the non-living instances, for example, bike, candle, toboggan, moon, by discussing the relationship between people, the instance, and energy. This illustrates the human-centred viewpoint of children's science:

> "... the candle's energy giving the light, as the energy, you've actually been given it, so in the dark, you could hold a candle and go around and you know where you're going." (candle, moon, 104)
>
> "Probably (the moon does use energy), it's just like us, if we went to run around the earth, we'd have to have energy to do it". (moon, 204)
>
> "Energy in holding on and pushing it back up the hill, it would be very tiring if you did it all day. Probably trying to keep your balance so you wouldn't fall off ..." (toboggan, 105)
>
> "Actually, they're having fun, but it's one thing taking (the) toboggan back up the hill, so you're using up your energy to go up the hill ..." (toboggan, 104)
>
> "That person would need, would have energy in his arms to steer, energy for him to move. He'd just need the energy in his arms, to when the bike stops, he'd need to get off, and he'd need his legs and need the energy in his legs and arms for steering it, steering the bike." (bike, 103, 301, 312, 310, 311, 509)
>
> "The bike doesn't (use energy) but the person riding it does ... He's using his energy to make the bike slow down. The bike's got no energy at all, it's not a living thing. (It's) the person that's using energy." (bike, 302)

Another aspect of the human centred view point is provided by four students who mentioned the need for willpower, thinking or messages from the brain, along with energy before living things could be active.

"Yes, he's using it to get up the stairs and willpower or something like that." (person on stairs, 106)

"Out of his body ... I don't really know where he gets it from but it must come from his brain to make him walk up the stairs which he uses energy." (person on stairs, weightlifter, 204)

"The brain ... telling the muscles to move whatever part of the body you want to move." (person on stairs, 401)

"Just sort of willpower that pulls themselves up ... just all the muscles, and strength in them."
(person on stairs, weightlifter, cow, 510)

3.3 Nine students attributed <u>human or living characteristics to inanimate objects</u>, with at least one instance:

"Well, the sun's energy has rays of light. It also has heat, and it can sometimes make a close watch, sort of, on the moon and the earth, and all the other planets, so it's sort of their father and their mother". (moon, 101)

"The earth would be moving round, and days and nights, and the moon would be going around to face the nights, so they'd have a moon". (moon, 107)

"Yes (the bike does use energy) because it's giving - it's letting that person ride ..." (bike, 309)

"Yes (the jack's using energy) gravitational ... the car wants to come down but the jack's holding it up". (car on jack, 511)

Two students, while they acknowledged that non-living things don't have a will or feelings, still indicated vestiges of this idea.

"The table's man-made, and it doesn't have any feelings, and, well, it's so strong that it just holds it up, and it doesn't need to eat or anything ..." (rock on table, 102, 103)

In Working Paper No. 15 "Living" we described the animism of some pupils in that machines e.g. the car, bike, and vacuum cleaner were considered living as they had working parts. An over-generalisation of the concept 'living' may influence the pupil's concept of energy:

"(What do you mean by "to use energy"?) well again, a person is energetic, and, also when something keeps parts working ..." (206).

"To be used, it's energy to turn all the things inside, the parts and bits are made to turn". (clock, 104, 201, 206, 313, 501)

3.4 Another everyday language use of the work energy, apart from the association of energy with living - moving objects, was the use of the word as synonymous with fuel. The phrases "energy crisis", "conserve energy" meant "fuel crisis", "conserve fuel". The pupils' responses indicated that this use of the word energy had promoted the notion that fuel is energy, rather than fuel contains or is a source of energy. This illustrates another expected aspect of children's science, that is, the reification of an abstract idea, expressing an abstract idea in terms of a concrete substance. The following quotations exemplify this:

"Uses petrol and that's energy".
(car 107, 100, 101, 102, 104, 105, 201, 302, 303, 305, 307, 310, 312, 314, 315)

"It might use petrol, it might use diesel, and both of those are energy". (hovercraft, 107)

Also expressed was the idea that if no fuel was being used then no energy was being used.

"The boat doesn't need energy because it moves with the sails up. Energy is not helping it to move. It is just by the wind, and the sea, and its sails. Doesn't need energy."
(yacht, 103, 104, 204, 206, 303, 304, 307, 502)

"I don't think (it was energy) .. it's going down a slope and I think it's something to do with gravity, and because it's going downhill and it doesn't need anything to - I mean, any engines or pushing or anything like that to make it go down."
(toboggan, 206)

The idea of energy as a fuel, relates closely to the idea that energy is used up. To a scientist the term "to use energy" means the transformation of energy. Most pupils interviewed used the phrase in the sense "to use the energy up", as with "to use the petrol up." The following answers were given in response to the question "What happens to the energy (while it's being used)?"

"... it's gone, it becomes no energy left, you know, when it's right out." (clock, 505, 314)

"It's been used up." (toboggan, 511; yacht, 108)

"The energy would be used up by making the picture show up." (television, 310)

"Oh, it's used up as the car goes further along." (car, 315, 316, 505)

"It's used up. The bird uses it up by flying, moving around." (bird, 102, 314, 505)

"Well, he wastes it. He's using it up. (Using it up until it's all gone?) Yes, then he has to get more energy." (person on stairs, 104, 511)

"He'd probably use it up and he uses it up and somehow it burns up - like when you burn a fire, the wood burns, and it turns into ashes. That can't burn any more after that, and it's got used up." (weightlifter, 206, 203)

The idea of "burning energy" like a fire burns fuel, was evident in the responses of the students.

"It gets all burnt up ... if you've eaten a lot of nice food, then you go for a run, you burn it up. So you don't put on weight." (person on stairs, 107, 314, 509)

"It's all burnt, used, then he'd need to keep on eating the right foods and that to get some more energy." (bird, 504, 506)

"It's burnt which makes the car move along, and once it's burnt, it's all gone, so you need more fuel." (car, 504, 206, 314)

"Gets burnt, gets burnt away." (candle, 505)

3.5 Energy as a concrete rather than an abstract idea

Children do find the concept of energy difficult to understand. They can cope to some extent with energy of living things and with energy as a fuel. However we detected a tendency, particularly where energy was introduced beyond the above boundaries, to deal with energy, or the question in a concrete rather than an abstract way.

The idea of energy as a physical substance, having a reality of its own, is indicated in the following responses.

> "Yes, (it does use energy), the flame burns the wax, and is the energy, and when the flame's burnt, it goes right down, the flame goes out, there's no energy." (candle, 102)
>
> "Yes (the yacht does use energy), energy is the wind, and the wind blows in the sails and the sails are connected to the mast, and the mast pulls it along." (yacht, 102)
>
> "Yes, it (the wind) is an energy." (yacht, 312, 314, 506, 511, 603)

That energy was a physical substance is reflected in more answers to the question "What happens to the energy?" where energy is viewed as a waste product like sweat, exhaust fumes or smoke.

> "He breathes it out." (weightlifter, 100)
>
> "It's used up in sweat or something." (weightlifter, 502)
>
> "It's .. goes out the exhaust." (car, 100, 107, 311, 309)
>
> "Most is discharged ... the exhaust, like body sweats ..." (car, 509)
>
> "If the hovercraft has a big funnel, it will go out the funnel. (The exhaust?) Yes." (hovercraft, 107)
>
> " .. it is usually all smoke ..." (candle, 101, 402)
>
> "It evaporates .. it's .. like water, it goes in the air and forms into clouds and that sort of thing." (car, 101)

The responses made about food chains or energy flow illustrated that the pupils had a notion of transference of energy from one living thing to another during feeding, and the utilisation of energy to sustain life, but both ideas were held without the more important and superordinate idea of energy transformation and conservation. The students were again dealing with the abstract ideas in a concrete way.

"Probably when it (bread) was wheat, just when the sun put energy into it, it would have got all stored up and things like vitamins and all those, and then when you mush it up, eat it, then it gives you energy." (person on stairs, 206)

"The sun, the food, the sun makes energy come from - the plant gets energy from the sun, and we get the energy from the plant, from the sun." (person on stairs, 303; cow, 105)

"(Have you heard of the phrase 'food chain'?) Yes, when you're talking about the one with animals - herbivore, carnivore, the predators, the main predator and the vegetation and things like that ... you'd start with the sun, the rain, the minerals, the cows eat it, digest it, cause it to change to the products it needs, and it's given off to consumers and people and plants." (end of interview, 312)

Some students did mention that living things used the energy they received in food but not in terms of energy transformation and conservation:

"The cow is eating the grass, and it's chewing it down, and the energy at the top of the grass is getting eaten by the cow, so the cow gets the energy and .. most of the energy .. and the grass keeps the other end .. it (the grass) uses (the energy) to keep it alive .. grow .. if the grass lost all its energy by the cows, you wouldn't have grass." (cow, 104)

Another way students had for dealing with an abstract question in a concrete way, was to describe the situation illustrated on the card rather than to discuss energy in relation to the situation.

"Well, may be burning, you get oxygen and things like that." (candle, 312, 107)

"Well, how do you start off a waterfall? You've got to have a flow of water, like you have to start it off like a mountain, which comes down a river which all the ice is just melting, it's just pushing the water in front of it .." (waterfall, 104)

Similarly the question,

"What happens <u>to</u> that energy when it's used?"

was often interpreted as "What happens <u>when</u> the energy is used?"

"The car doesn't go." (car, 102)

"Oh, just eat something else, then you'd get energy again or just lying around you get energy .. then you can stand up and start running." (person on stairs, 301)

"It (the moon) moves, keeps using up the energy, over and over again." (moon, 510)

"Just run down, because there'd be no more energy to keep it going." (clock, 501, 311, 104)

"Oh, all the water goes out to sea ..." (waterfall, 314)

4. Aspects of students' answers with implications for teaching.

In Section 3 we detailed various aspects of children's science as they related to energy. The use of energy in the everyday sense, with its close associations with living things, movement and fuel, has been explored. We have also identified those aspects of children's human centred and animistic viewpoints which have been identified in all our other studies (for example see Working Papers 15 & 16; Living and Force). These views of children all have implications for the teaching of ideas about energy. However, in this section we will consider other specific aspects of children's views about energy which also have implications for teaching.

4.1 Conservation of Energy

One of the main aims of school physics is to teach students that energy is not created nor destroyed but is simply converted from one form to another. It was very rare indeed for students, other than sixth form students, to mention the idea of energy being transformed. The following responses were given to the question "What happens to energy?" and illustrate student responses that contained the idea of energy transformation:

"It's turned into heat and light" (candle, 201)

"It (the electrical energy) gets changed into the picture and the sound ... and some of it gets wasted - lost, being used up ... the electricity - the energy that comes in ... it gets changed into the sound and the colour of the picture." (television, 505)

"The bike possesses energy at the start, and then after slowing down, it possesses less energy. So it must be using energy, yes, it must be giving up its energy of motion, kinetic energy, in the form of heat, yeah, mostly heat and other forms. Being transformed into heat by friction, by rubbing ..." (bike, 601,602)

"... he's getting potential energy by walking up the stairs because if he suddenly jumped off them, you'd have a whole lot of potential energy that would be converted to kinetic energy." (person on stairs, 603, 601)

As we noted earlier, many students equated energy with fuel and considered that energy gets used up or burnt up. While this idea may be appropriate in terms of the conservation of useful forms of energy it is easy to see that the principle of conservation of energy can be confused by students with an attempt to conserve fuel.

Perhaps of even greater pertinance to those involved with fuel-conservation education programmes were the views of some students that fuels, and other so-called energy sources, were not, in fact, related to energy.

"I don't think that the car would have energy because the car's got a motor. A car, although it moves, I don't think it needs energy ... it's just the petrol that it's using up." (car, 103, 508)

"No (a car does not use energy) because the car runs on petrol and water and oil, it doesn't need the sun." (car, 204)

"... the car's not (using energy) because it's going by itself. Doesn't need anything to make it go. Just petrol and that." (car, 301)

"Oh, it (the energy) is not really used all that much, for a car. Just more or less alone by battery and power ... the motor and stuff in the car." (car, 510)

"I don't think the television needs any energy. It's going by electricity ... " (television, 103, 204, 301, 503).

These views can be interpreted as energy not being required in the same way living things need food to be active or energetic. In this sense they link back to the ideas detailed in 3.1 and 3.4.

4.2 Confusion between physical Phenomena

We have identified in a number of our other studies, e.g. Force, that students, particularly after having been taught some science, confuse various physical phenomena. In this study, words such as 'gravity', 'friction', 'force' were used in a confused manner (from a scientific point of view) when discussing energy.

A number of examples occurred when gravity was confused with energy;

> "Yes, (the moon's) using the earth's energy of gravity." (Moon, 201, 312, 506)
>
> "It's mainly weight and gravity involved in this. Gravity and icy slope, which has got a slippery surface, helps gravity make it go down, and that adds to the force of gravity. That's the main energy involved in it." (toboggan, 312, 316)

Friction was confused with energy;

> "(Does the bike use energy as it slows down?) Ah, friction (Friction. Is that energy is it?) Yeah - the axles and tyres." (bike, 316, 509)
>
> "... there'd be a bit of energy in the wheels between the ground and the wheels. (Between the ground and the wheels?) Yes, friction again. (So you see friction as a form of energy do you?) I'd say it might be a form of energy." (bike, 501, 506)

Force was confused with energy;

> "(What happens to the energy?) It's being used and since you can't lose energy, it's being converted to some other form, heat or ... it must be converted into a force, in a way, because it's operating an opposite force on the gravitational force. (So the energy is changing into a force?) Yes." (weightlifter, 603)
>
> "Yes (he is using energy) ... using a force to get up there, the force of energy." (person on stairs, 205)

The word 'force', was also used in an everyday sense in the verb form (see Working Paper No 16, Force).

> "Yes, gravity is trying to force the bar down to the ground and he's using energy to hold it in place. He's fighting against a force, so he's using energy again." (weightlifter, 502)

> "(Where does the energy come from?) I d say it would be stored up in here. When the man turns the key, he's forcing energy into the clock". (clock, 501)

> "The rock's forcing down on the table, and the table's just sitting there, so the rock's forcing against the table." (rock on table, 511)

Some students had confused doing work (using energy) to holding something still, against the force of gravity, and moving it against the force of gravity.

> "Yes (the table does use energy to hold up the rock) because if the table wasn't strong enough and the rock was heavier it would probably break the table." (rock on table, 309)
> (car on jack, 304, 308, 311, 315)

> "Well, I suppose there has to be something holding it up. So whatever is holding it up, must ... must be using energy to hold it up." (car on jack, 316, 401, 505, 510, 511)
> (rock on table, 304, 313).

Potential energy was confused with the potential to have energy. Although this is an example of children's science, in that it is a confusion with the everyday use of the word, it is included in this section as only students who had been taught science tended to use che words 'Potential energy'.

> "(What does potential mean to you?) Heat energy, the heat from the fire or something, can be used to heat water and is a source of energy to heat the water, and to cook things." (504)

> "Potential energy is when something has the potential to have energy, like that rock ... and the bar ... the car's not moving but it is - if it was let go, the person holding it up, let it go, it would fall. It would be it's energy." (505)

> "(You said potential energy?) Yeah, you could use all that ... water as for hydro-electricity, you know, make hydro-electricity, so it could be used for energy. Potential energy is not energy at all but it could be converted to energy - you could get energy out of it - it's just like if someone potentially bright they've got it but all it needs is developing it." (505)

"Potential energy ... stored energy ... there's no energy in it now but if you threw it, there'd be kinetic energy when it's moving .."
(rock, 507)

4.3 Examples of different kinds of energy and sources of energy.

At the end of the interview the pupils were asked "Have you heard of the different kinds or types of energy?" "Could you describe them?"

Some pupils (204, 205, 308, 602) could name none. Most could only recall one or two different kinds. Those mentioned were nuclear, light, solar, mechanical, heat, kinetic, and stored energy.

Also named as types of energy were:

1. Sources of energy - oil, steam, hydro-, geothermal, battery, wax.
2. Things that use energy - engine, body.
3. Others - gravitational, friction.

Examples of these 'types' of energy are also exemplified in students' answers to the question used in the interviews, "Where does the energy come from?". Answers students gave to this question, in specific instances, are detailed in Appendix B. In summary, the sources mentioned included (the particular instance and the number of students in brackets),

Air, oxygen	(candle (8), moon (7))
Power	(television (6))
Electricity	(television (16))
Petrol	(car (12), hovercraft (7))
Grease, oil	(bike (1))
Wax	(candle (4))
Engine, motor	(car (3), hovercraft (1), car on jack (4), clock (4))
Sun	(moon (11), bike (1), rock on table (1))
Living things	(car on jack (1), clock (14), bike (7)
Wind	(yacht (24), moon (1), bike (1))
Inner energy	(moon (4), jack (1))

With regard to living things the sources of energy were given as:

Food	(person on stairs - (12), weightlifter (4), bird (6), cow (1))
Muscles	(person on stairs (1), weightlifter (2), bird (1))
Arms, legs	(person on stairs (1), weightlifter (2))
Body and body fat	(person on stairs (1), weightlifting (1))
Heart and blood	(person on stairs (4), weightlifter (2))
Physical fitness	(weightlifter (7), bird (1))
Relaxation	(person on stairs (3), person on bike (1))

For six students, the source of energy for plants was the soil, and from the sun indirectly.

> "He (the teacher) got us to do a couple of experiments on, if a plant needs energy, and if it needs the light, and where does it get its energy from and how they gain it, and he did one with - one group had to try different kinds of plants, underneath, if the plant will grow in it. And (we) found that it will grow only in the soil, seeds will only grow in soft soil, garden soil, it won't grow on blotting paper and sawdust, and (the teacher) said that energy, it's going from the soil, all the little insects or whatever is in there, and suck it up, it helps grow - the seeds grow bigger (So they get their energy from the soil?) Yes." (103)

> "And the grass gets the energy from the dirt, and the dirt gets the energy from the sun." (cow, 104, 103, 105, 311, 508, 511; person on stairs, 104)

> This idea was extended to include the soil as a source of energy for the worm.

> "The worm lives in the ground, and like I said before, the sun gives the ground energy so the worm gets the energy and the bird eats - which gives the bird energy." (bird, 104, 205)

This may arise from the lack of knowledge that, although a worm eats the soil, it utilises only the decaying organic material as food.

That the soil as a source of energy in conjunction with the sun or water, was also mentioned:

"(Where does the grass get that energy from?) From the soil and when it rains it gets energy from there and the sun." (cow, 107, 507)

Seven students also held the idea that warm-blooded animals use the sun directly as a source of energy. This idea was often held in conjunction with food as an energy source.

"These animals (iguanas), they lie in the sun, because they're so cold, and then they go ... when they're warmed up, they can really go, move fast. (What about us, can we sit in the sun and get energy?) Yes ... (What about a person who lived inside all the time, and wouldn't get out? Where would he get his energy from?) By food and water." (person on stairs, 104, 303)

"His body - no, the sun and vitamin A and C, things like that." (person on stairs, 310)

"(So where does the cow get that energy from?) The sun, water, the rain too, the nourishment in the ground." (cow, 312, 507)

"The cow would be getting its energy out of the grass and the sun. (In what way does the cow get energy from the sun?) Most probably through the rays of sunlight, most probably goes into its body and does something. The sun's on the grass and puts protein in the leaves or something into the grass." (cow, 313)

5. <u>The scientific perspective</u> and teaching ideas about energy

Section 3 and 4 of this paper gave many examples of energy in relationship to children's science and the non-scientific views that students who have been taught some science, can hold. We have emphasized these views as we consider they are prevalent and it is important to identify them. On the other hand, we did find students who had views compatible with the scientific perspective. Many sixth formers we interviewed did have reasonable ideas about the principle of conservation of energy. They could, and did, distinguish between the scientist's view of force, work and energy.

> "Yes, they're doing work, they're applying a force, and they're moving and since energy is the capacity for doing work, then it must be - since they're moving, they must be using up energy." (person on stairs, 601, 602)

Some fifth as well as the sixth formers did distinguish between kinetic and potential energy:

> "Kinetic energy is - caught up with the motion of something, the movement, moving along like the bike." (504, 602)
>
> "There'd be kinetic energy while it's moving because that energy is moving energy." (507)
>
> "Potential energy - it's energy stored or can be used". (511)
>
> "Potential energy is energy that is stored, that can be converted to another form if energy to be used." (60[illegible])

Further, many students had views not entirely incompatible with a scientific perspective:

> "To apply a force, you're using energy." (car, 402)
>
> "Oh, he's got to pull his body up, (it's) a dead weight. He's got to use some kind of force to get it up, so he does use energy." (person on stairs, 501, 502, 505, 507, 510, 511)
>
> "It might need a bit of energy to get it moving to start with - someone pushing it." (toboggan, 108, 105, 201, 205, 313, 401, 402, 501, 506)
>
> "Gravity pulling it downward, so it would be using energy as it goes along." (toboggan, 602; Moon 307)
>
> "It uses energy to fall ... gravity pulls the water down." (waterfall, 201, 602)

Finally, it must be said that many of the younger students' views were not necessarily incompatible with the scientists' views. Rather, they need to be carefully modified and qualified to make them more compatible with the scientific perspective.

Final comment

This paper has described some children's views about energy. As with other words used in science that we have investigated, children have and tend to retain the everyday use of the word. Energy is

associated by children with living things, with movement and with fuel. To many children it is a rather abstract idea which they tend to think about in concrete ways, in terms of human viewpoints and experiences, and in terms of everyday usage of associated terms, e.g. potential and conservation.

Teaching about the scientific view of energy is as difficult as learning about energy. It would appear to us that we must learn how to modify and qualify childrens' views to make them more scientific. For example:

(i) Children's ideas about energy, being associated with living things, need to be extended to energy associated with non-living things; energy in the biological world needs to be taught in conjunction with energy in the non-living world.

(ii) Ideas about force, gravity, work and heat need to be gradually separated and distinguished from ideas about energy.

(iii) The term 'use energy' needs to be modified from 'use energy up' to 'use energy in one form will result in energy in another form'.

(iv) Conservation of energy needs to be carefully distinguished from conserving energy; fuel needs to be distinguished from energy.

(v) The association, or lack of association, between movement and energy needs to be clarified.

(vi) Potential energy needs to be carefully distinguished from the potential to create and store energy.

It is our belief we have to start where the child is. How far we can, or should try to, convert children to a more scientific perspective is a major question.

If you have reactions to this paper, or ideas about how energy should be taught which builds on the child's perspective we would like to hear from you.

References

Osborne, R.J. and Gilbert, J.K. (1979), Investigating students understanding of basic concepts using an interview-about-instances technique, Research in Science Education, 9, p 85-93.

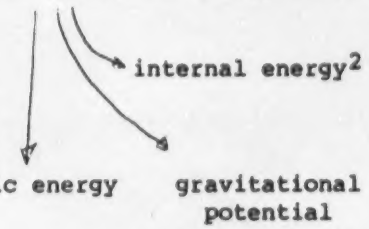
Acknowledgements

I wish to thank Roger Osborne, Peter Freyberg, Keith Stead, and Ross Tasker for the valuable discussions and advice related to the interviews and the writing of this paper.

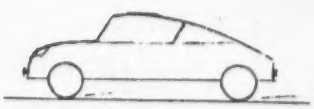
APPENDIX A

1. Person on stairs

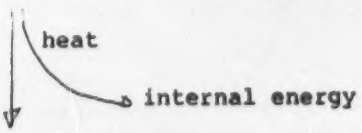
Chemical potential energy in body



2. Car moving along the road



Chemical potential energy in fuel

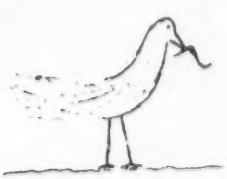


Kinetic energy of parts and to whole car.

3. Weightlifter holding a bar stationary over his head

chemical potential energy

4. Bird eating worm

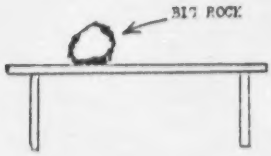


chemical potential energy in the worm is being transferred to the bird, and the chemical potential energy of the bird

2 By internal energy we do not mean energy "internal" to the body, rather we mean the energy associated with the increased temperature of the body and the surroundings.

5. Rock on table

no energy conversion or transfer



6. Burning candle

Chemical potential energy in the wax

- internal energy
- light (and other radiant energy)
- sound

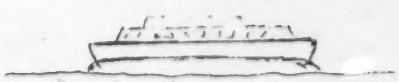
7. Bike slowing down

Kinetic energy of bike

↓

internal energy

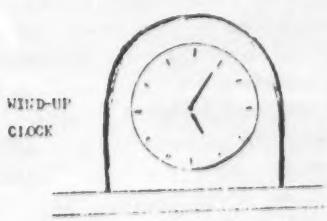
8. Hovercraft



Chemical potential energy in fuel

- internal energy
- kinetic energy of air particles which is transferred to the hovercraft

9. Wind - up clock



Kinetic energy of person

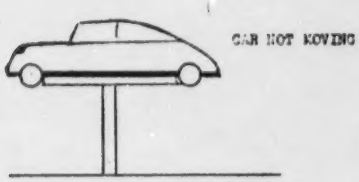
↓

elastic potential energy in spring

- heat
- kinetic energy of hands
- internal energy

10. Car on jack

No energy conversion, or transfer



11. Yacht

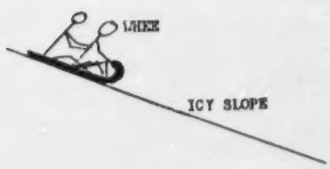
Kinetic energy of air particles is being transferred to the yacht, plus internal energy of water.

12. Toboggan on Icy Slope

Gravitational potential energy of toboggan

↓

kinetic energy of toboggan and a small amount of internal energy in the snow and toboggan



13. Waterfall

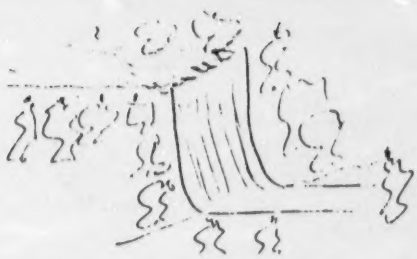
Gravitational potential energy of water

↓

kinetic energy of water

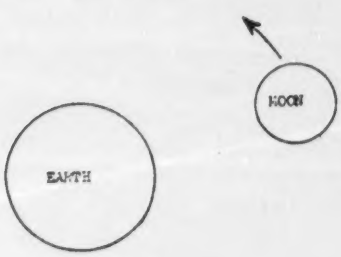
↓

internal energy of water (temperature rise)

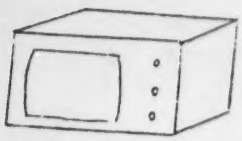


14. Moon and earth

No energy is being converted. There are no air particles or atmosphere around the moon or in space and therefore no force of friction needs to be overcome. A moving object, will keep on moving at a constant speed unless acted on by a force, which has a component in the direction of motion.



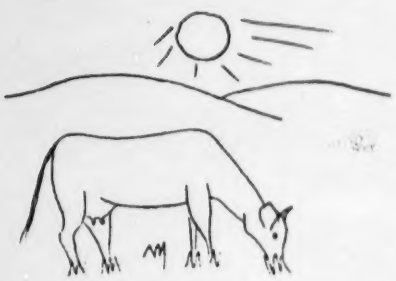
15. Television



electrical energy

light, sound internal energy

16. Cow eating grass



Light energy from sun (photosynthesis)

(photosynthesis)

chemical potential energy in grass respiration

internal energy

transferred

chemical potential energy in cow

respiration

internal energy

APPENDIX B: WHERE DOES THE ENERGY COME FROM?

The answers given to the question "Where does the energy come from?" also suggest the pupils viewed energy in terms of transference, not transformation. To them, the energy is obtained from something, not converted from another kind of energy. The sources of energy mentioned were:

1. Air, oxygen

"It needs energy - the energy it needs is the oxygen around it." (candle, 100, 101, 206, 307, 312, 315, 504, 511)

"(Where would the moon get the energy from?) The atmosphere." (moon, 312, 101, 103, 206, 314, 402, 510)

2. Power

"Yes, it uses the power, so it takes energy to make the power go." (television, 203, 313, 507, 509, 510, 511)

3. Electricity

"Yes (it uses energy) - goes by electricity" (television, 105, 104, 303, 307, 308, 309, 311, 312, 401, 402, 502, 504, 505, 506, 602)

4. Batteries

"Yes, (it does use energy) it's got batteries in it..." (television, 305, 206)

"(Where would the car get the energy from?) The battery" (car, 311, 510).

5. Fuel

(1) Petrol

"Yes (the car does use energy) it gets petrol ... without petrol it wouldn't go so it must have some energy." (car, 203, 206, 308, 316, 502, 504, 505, 506, 507, 601, 602, 602)

"Yes, I think so (it uses energy) because it needs petrol." (hovercraft, 206, 201, 302, 303, 503, 506, 509)

(2) Grease, Oil

"Yeah, it would be (using energy). If it had any grease in the hub, because the grease is made from petroleum products." (bike, 303)

(3) Wax

"(There's) energy inside the wax ..." (candle, 103, 107, 314, 505)

6. Motor, Engine

"(Where does that energy come from?) the engine." (car, 100, 309, 504) (hovercraft, 505)

"Yes (it does use energy) to get it up there in the first place, it would - and to hold it there, they'd have to be using some sort of energy to hold it there. Could be some sort of air or ore or a motor or something." (car on jack, 502, 201)

"(Where would it get the energy from?) The motor or electricity or something." (car on jack, 311, 510)

"(Where does the energy come from?) the engine of some sort, when you wind it up ... probably fill the machine or something ..." (clock, 503, 309)

"(Where does that energy come from?) ... the spring inside." (clock, 316, 602)

7. The Sun

"(Where does the earth get its energy from?) I think the earth uses the sun." (moon, 102)

"(Where would it get that energy from?) The sun." (moon, 204, 101, 104, 205, 206, 302, 402, 501, 502, 507)

"From the air, and the sun, probably the sun. I think. (We are talking about the bike, not the person?) Yes, sunlight, it's against the metal and probably gets in somehow." (bike, 206)

"(Where did it (the rock) get the energy from?) The sun. The sun provides just about everything with energy." (rock on table, 104)

8. Living Things, e.g. People

"(Where would it get that energy from?) The person that pushes it up." (car on jack, 308)

"The person that winds it up gives the clock energy to move." (clock, 100, 101, 104, 105, 201, 205, 303, 308, 310, 313, 314, 401, 501, 511)

"... the energy comes from when we are pedalling it." (bike, 102, 201, 205, 309, 504, 505, 510)

9. The Wind

"The wind would give it energy to move." (yacht, 105, 100, 101, 108, 201, 205, 301, 303, 305, 308, 310, 311, 313, 314, 316, 401, 402, 501, 505, 507, 510, 511, 602, 603)

"(Where does it get that energy from?) Probably out in space, there's probably currents that make it move around." (moon, 107)

"(Where would it get that energy from?) Oh, the wind blowing against it and it would be forcing it straight - it's greater than the force of the wheels." (bike, 309)

10. Inherent Energy

"(Where would that energy come from?) The stored energy. I don't know. There's no-where for it to get energy from. Maybe the sun. I don't know. I think everything's got a little bit of energy ..." (moon, 507, 501, 511, 315)

"(Where did it get that energy from?) I don't know. Just everything's got energy somehow, until it moves." (jack, 507)

For living things the sources of energy were:

1. Food

"From his food." (person on stairs, 206, 102, 103, 105, 106, 107, 304, 307, 402, 503, 506, 602)
(weightlifter, 206, 303, 401, 502)
(bird, 100, 102, 103, 301, 503, 504)

2. The body or Body Parts

(a) Muscles

"His muscles." (weightlifter, 100, 313) (bird, 101)

"Probably from the muscles, provided by ATP and other chemicals which allow muscles to contract, mainly chemical reactions within the body." (person on stairs, 601)

(b) Arms, Legs

"The legs. Achilles' tendon. Back legs, um, muscles in his thighs and that." (person on stairs, 312)

"From his legs really, because the legs have to stand more of it and the arms are just holding it up." (weightlifter, 301, 308)

(c) The body and body fat

"Just from the body - fat and that ... (from) food." (person on stairs, 314)

"His body ... he'll have all the energy stored in his body and when he's lifting something up, it will help him to lift it up, as he'll be using kinetic energy." (weightlifter, 501)

(d) The Heart and Blood

"The blood. The heart pumps the blood around all the body, muscles, organs - muscles use the blood for energy." (weightlifter, 201) (person on stairs, 201)

"Food in our body that we give to ourselves, forms the energy, I think it goes into our blood, and the blood flowing gives you strength." (person on stairs, 302, 313)

"Body, again. Be broken down. Heart and something." (weightlifter, 509)

3. (a) Physical fitness

"Like people get fit for the Olympics and they do a whole lot of exercises and they pull and push muscles, and they lift weights like he's doing and they can go on ... (He's getting his energy because he's strong and fit?) Yes." (weightlifter, 104, 311, 302, 309)

"From eating the right foods and working hard to build up muscles to lift it." (weightlifter, 107, 105, 508)

"Strength building machines and that." (weightlifter, 205)

"The bird gets out and flies around, exercises it." (bird,-311)

(b) Relaxation

"Oh, food you eat ... sleep, and exercise and that." (person on stairs, 315, 203, 504)

"You're probably getting more energy when you slow down and just relax." (bike, 105)

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